

Internal Structure of Earth and Plate Tectonics

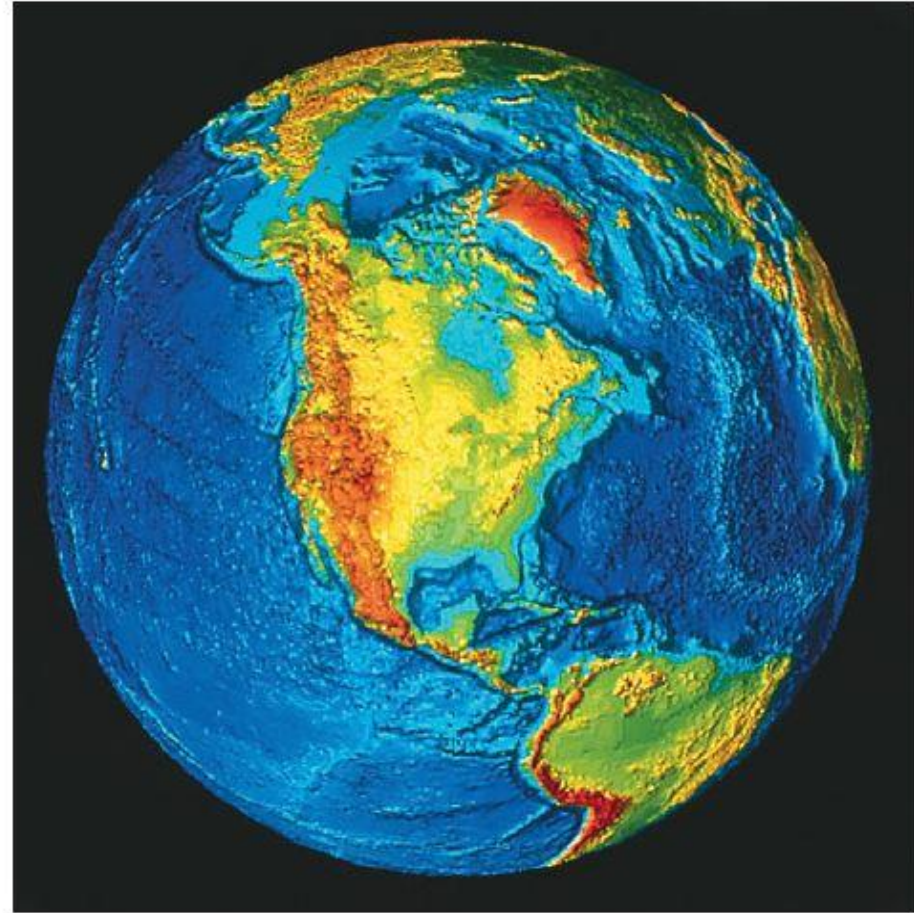
Chapter 2

Learning Objectives

- **Understand the basic Internal Structure and Processes of the Earth**
 - **Know the basic ideas behind and evidence for the Theory of Plate Tectonics**
 - **Understand the Mechanisms of Plate Tectonics**
 - **Understand the Relationship of Plate Tectonics to Natural Hazards**
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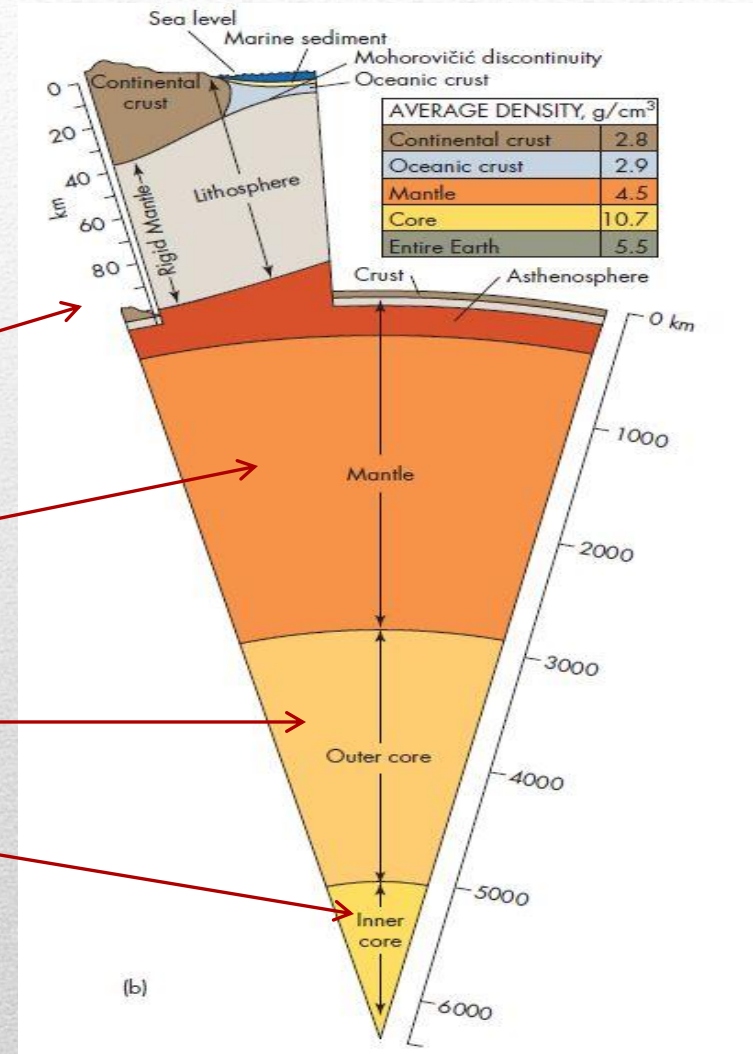
The Internal Structure of Earth

- The Earth is a complex dynamic planet
 - By composition and density (heavy or light)
 - By physical properties (solid or liquid, weak or strong)
 - The Earth has a rigid outer shell, a solid center, and a thick layer of liquid that moves around as a result of dynamic internal processes
 - The Internal Processes are responsible for the effecting the surface of the earth
-



The Earth is Layered and Dynamic

- Composition of the Earth's Interior
- Crust with a variable thickness
- Mantle surrounding the outer core
- Liquid Outer Core
- Solid Inner Core



The Earth is Layered and Dynamic

- The Inner Core

- Solid and very dense mass having a radius of 808 miles

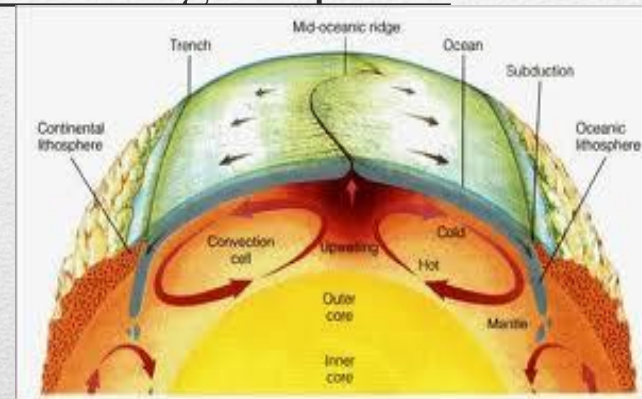
- Both the inner and outer core are made of **iron/nickel** or **iron/silicate**.
- Makes up **15%** of the Earth's volume and **32%** of its mass
- The Earth's **magnetic field** is generated primarily in the outer core
- Magnetic field changes over time from the North Pole to South Pole

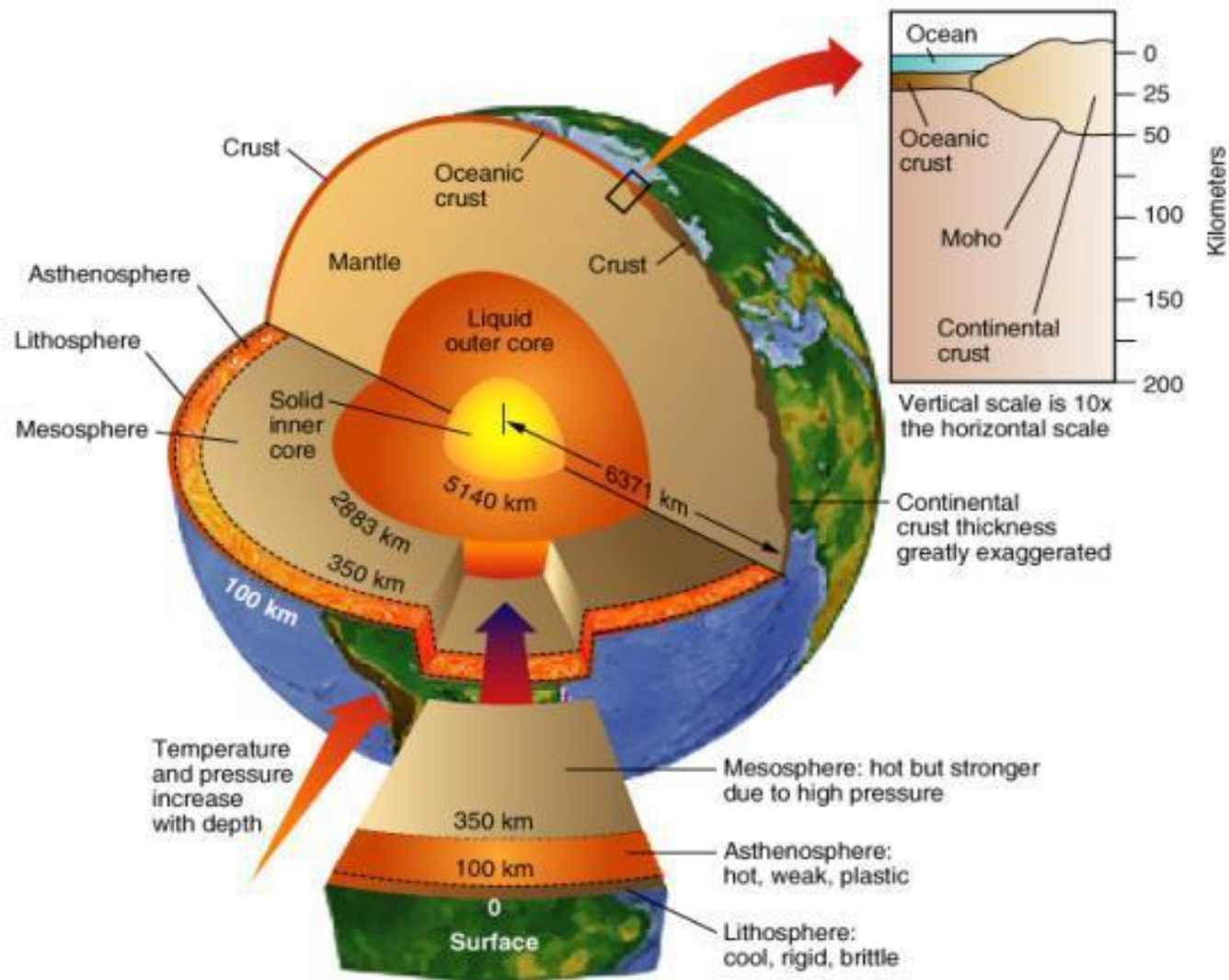
- The Outer Core

- Molten and extending to a depth of about 1243 miles
 - Composition is similar to the inner core
-

The Earth is Layered and Dynamic

- Above the Inner Core is the **Mantle (1864 miles)** where there is a change in mineral composition
 - The **Mantle** is where convection takes place moving the plates
 - Between the **Mantle** and the crust is the
 - **Mohorovicic discontinuity (or Moho)**
- The **Crust** is the outermost hard shell, consists of a broad mixture of rock types
- This is called the **Lithosphere** (from the Greek word for rock)
 - Average thickness averages 3 miles, between continental and ocean crusts
 - The continents' crust averages more than 5 times that of the oceans crust

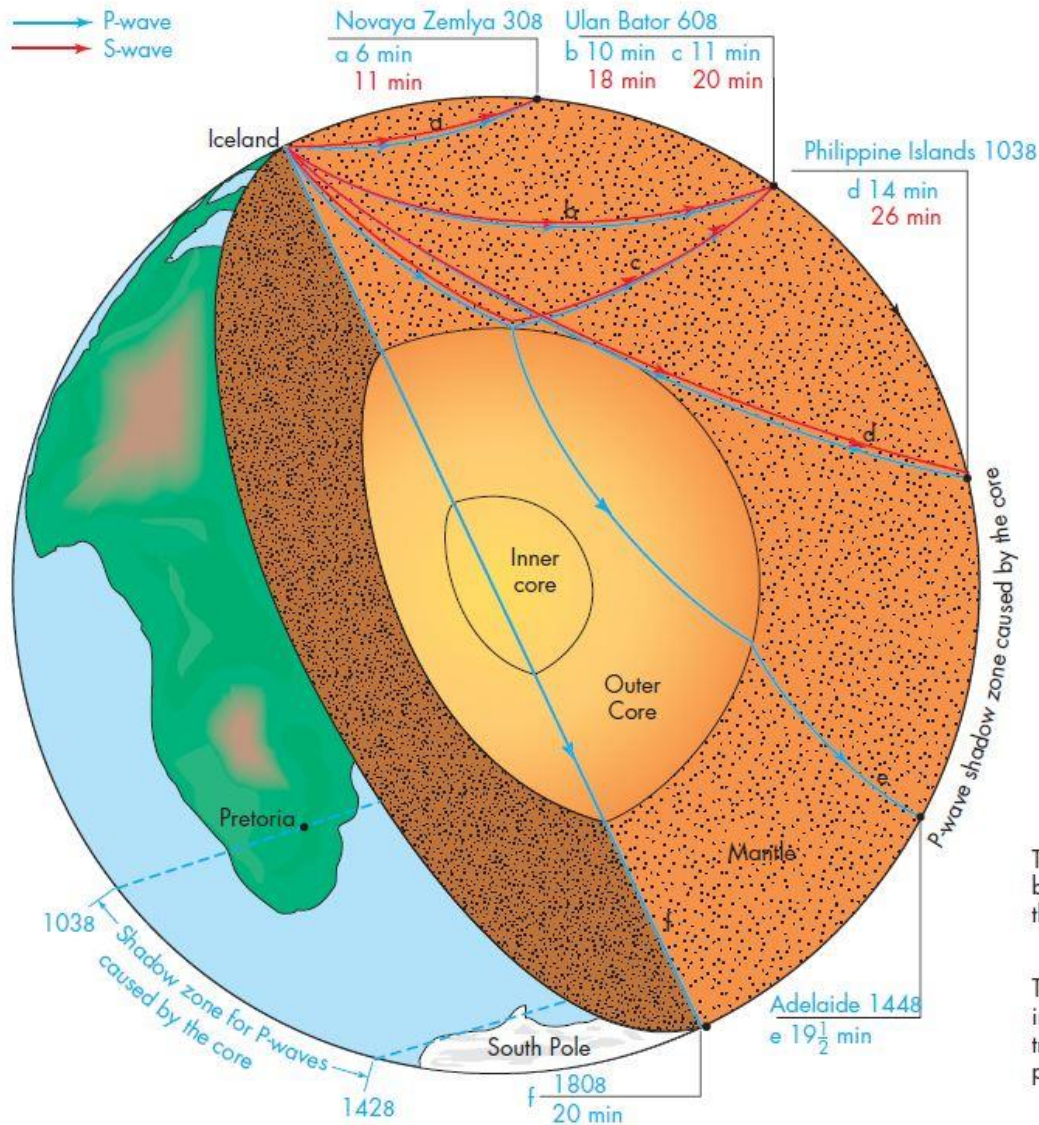




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How Do We Know About the Internal Structure of Earth

- We have learned about Earth through the study of Earthquakes
 - This study is called **Seismology**. Through this science, we have learned about the structure of the Earth.
 - Seismology is the study of earthquakes and the passage of seismic waves through the earth
 - These waves are called P waves and S waves
 - ❖ These waves travel through the earth at different rates
 - ❖ It is through the study of the travel of these waves that Seismologists have been able to describe the center of the earth.
 - These studies have been able to determine
 - Where magma is generated in the asthenosphere
 - The existence of slabs of lithosphere that have apparently sunk deep in the mantle
 - The extreme variability of lithospheric thickness, reflecting its age and history
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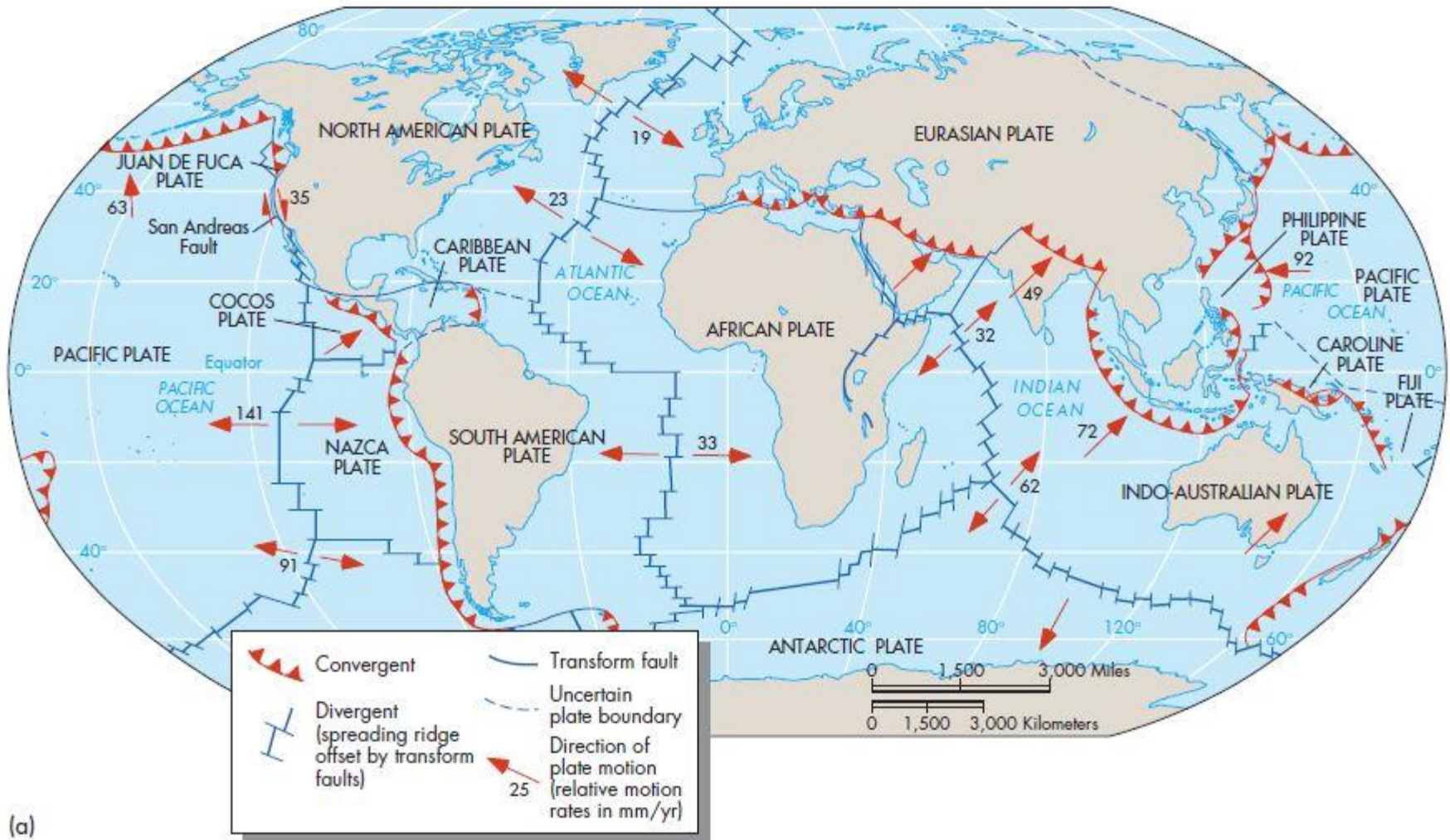
The mantle. Travel times for pathways such as a, b, and c indicate that seismic waves travel faster the deeper they penetrate the mantle

The core. P-waves travel considerably more slowly in the core than in the mantle, and S-waves are not transmitted at all. This indicates that at least the outer part of the core is liquid.

Plate Tectonics

- The term tectonics refers to the large-scale geologic processes that deform the Earth's lithosphere.
 - Movement of the lithospheric plates
 - What is Plate Tectonics???
 - Processes associated with creation, movement, and destruction of the *lithospheric plates* collectively are called plate tectonics
-

Plate Boundaries



(a)

Plate Tectonics

- Locations of earthquakes and volcanoes define Plate Boundaries
 - Plates may include both a continent and part of an ocean basin or an ocean region alone
 - Some plates are very large, some are very small, are relative to their location
 - Most earthquakes and volcanoes are associated with the interactions of the plate boundaries, mostly defining where they are
 - Over the geologic time, plates are formed and destroyed, cycling materials from the interior of the Earth to the surface and back again
 - This is the Tectonic Cycle
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Earthquakes & Volcanoes

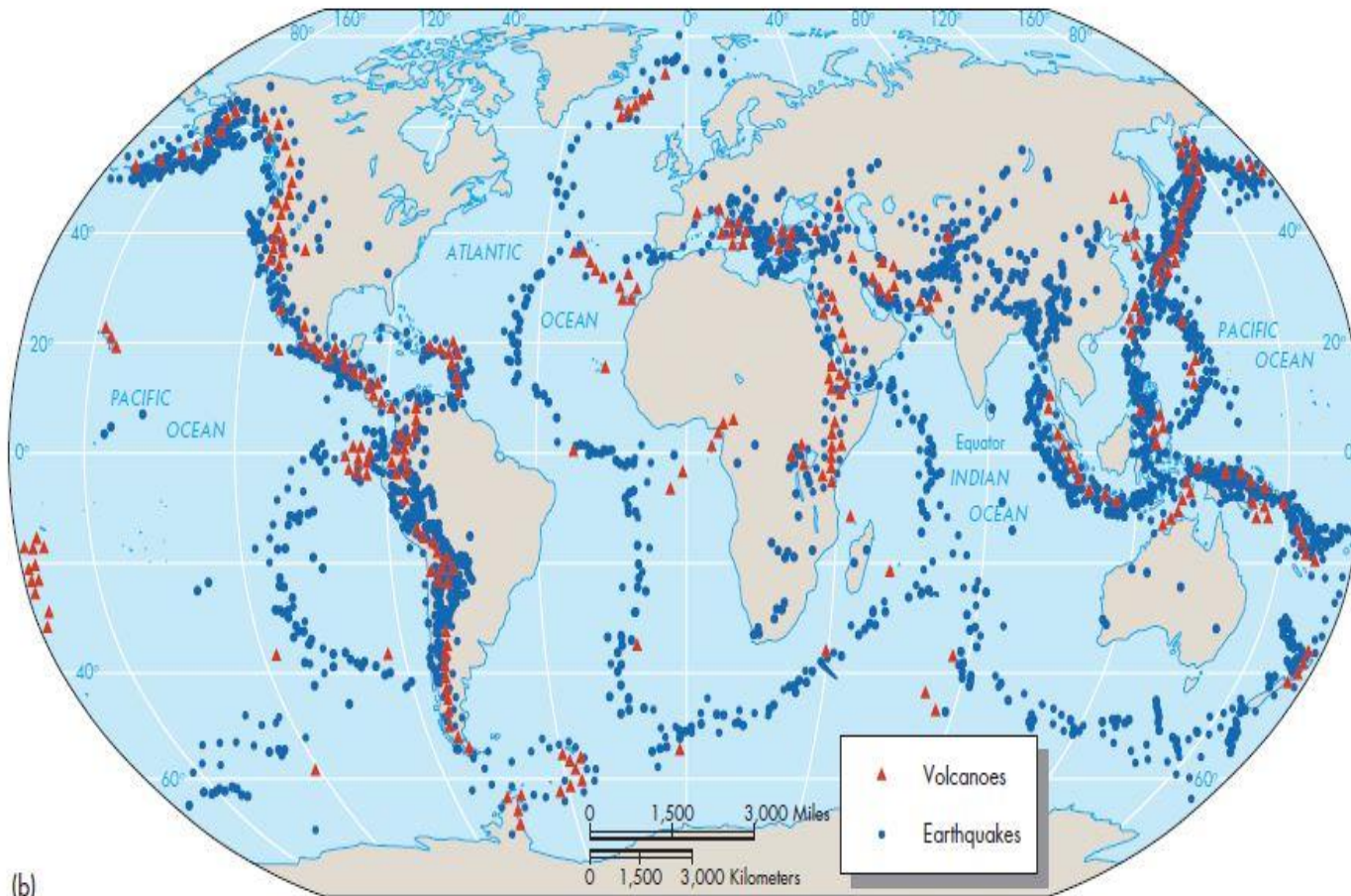
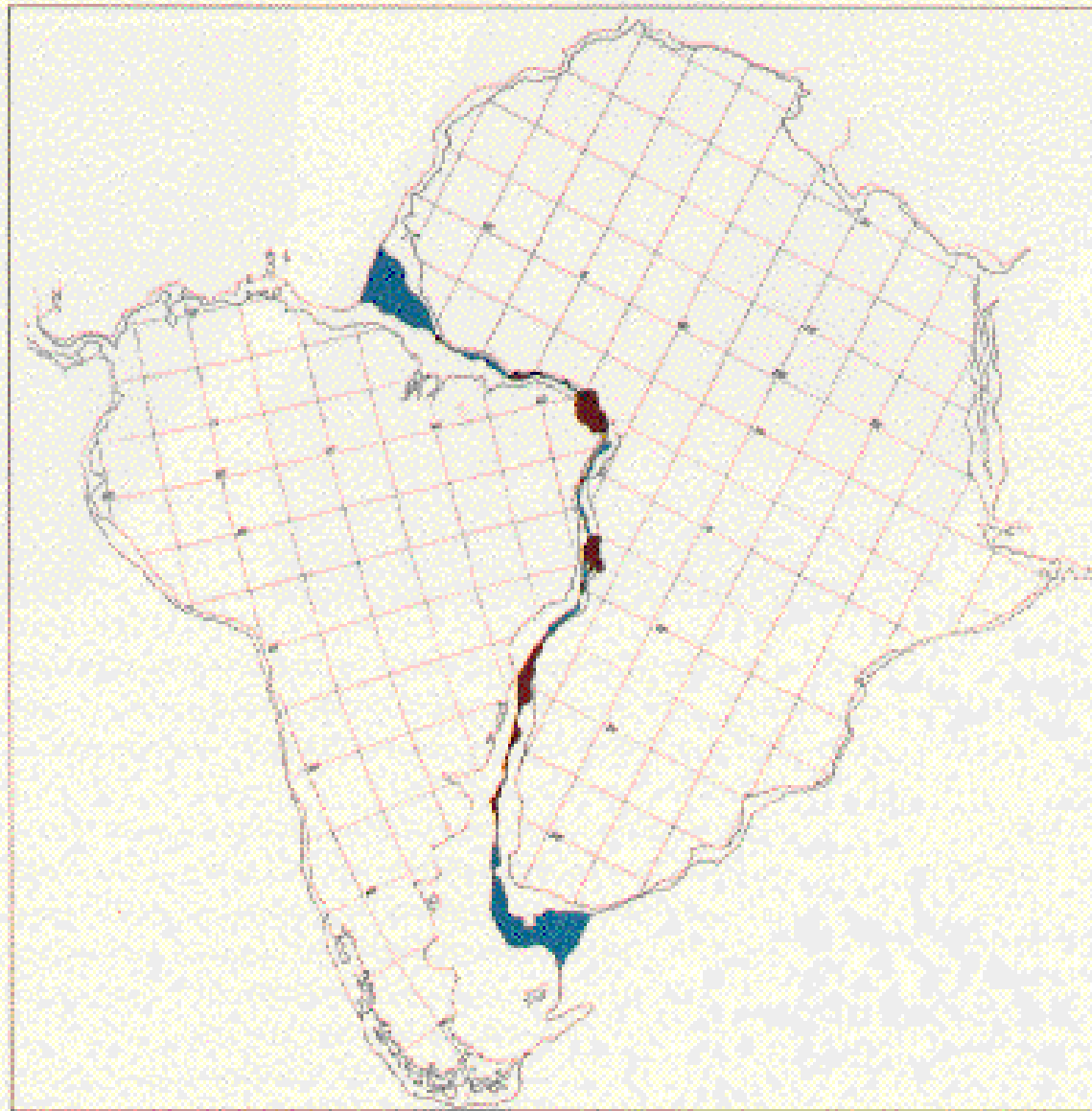


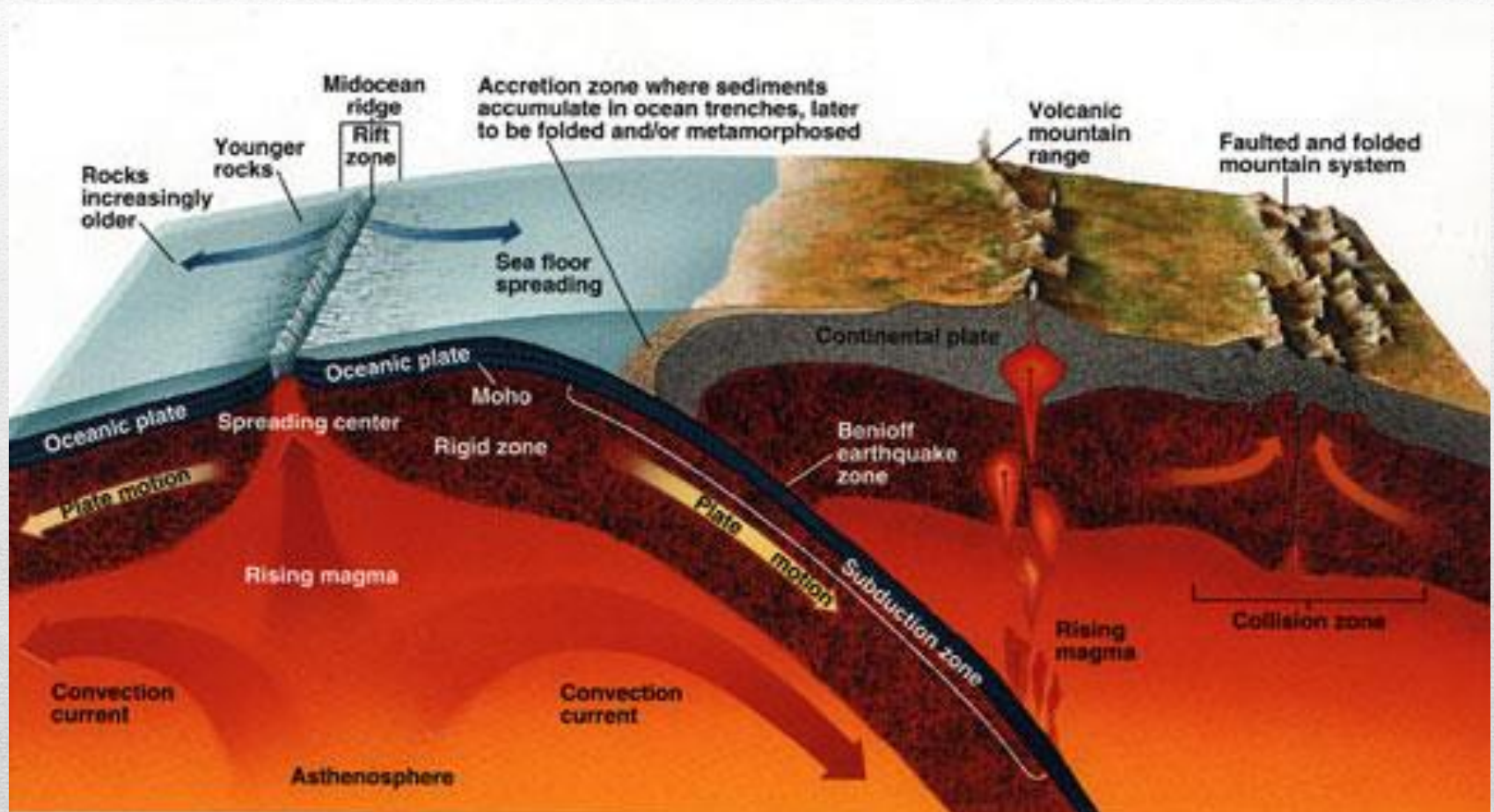
Plate Tectonics

- Seafloor Spreading is the Mechanism for Plate Tectonics
 - As plates move over the asthenosphere, they carry the continents embedded within them
 - ❖ This idea was first suggested by a German scientist Alfred Wegener in 1915.
 - ❖ He suggested the theory of *Continental Drift*, based on the congruity of the shapes of the continents across the Atlantic Ocean
 - ❖ He also looked at shapes of both South America and Africa and theorized that the shapes of the two continents fit as if they once were one
 - ❖ In the late 1960's this theory was finally accepted when seafloor spreading was discovered
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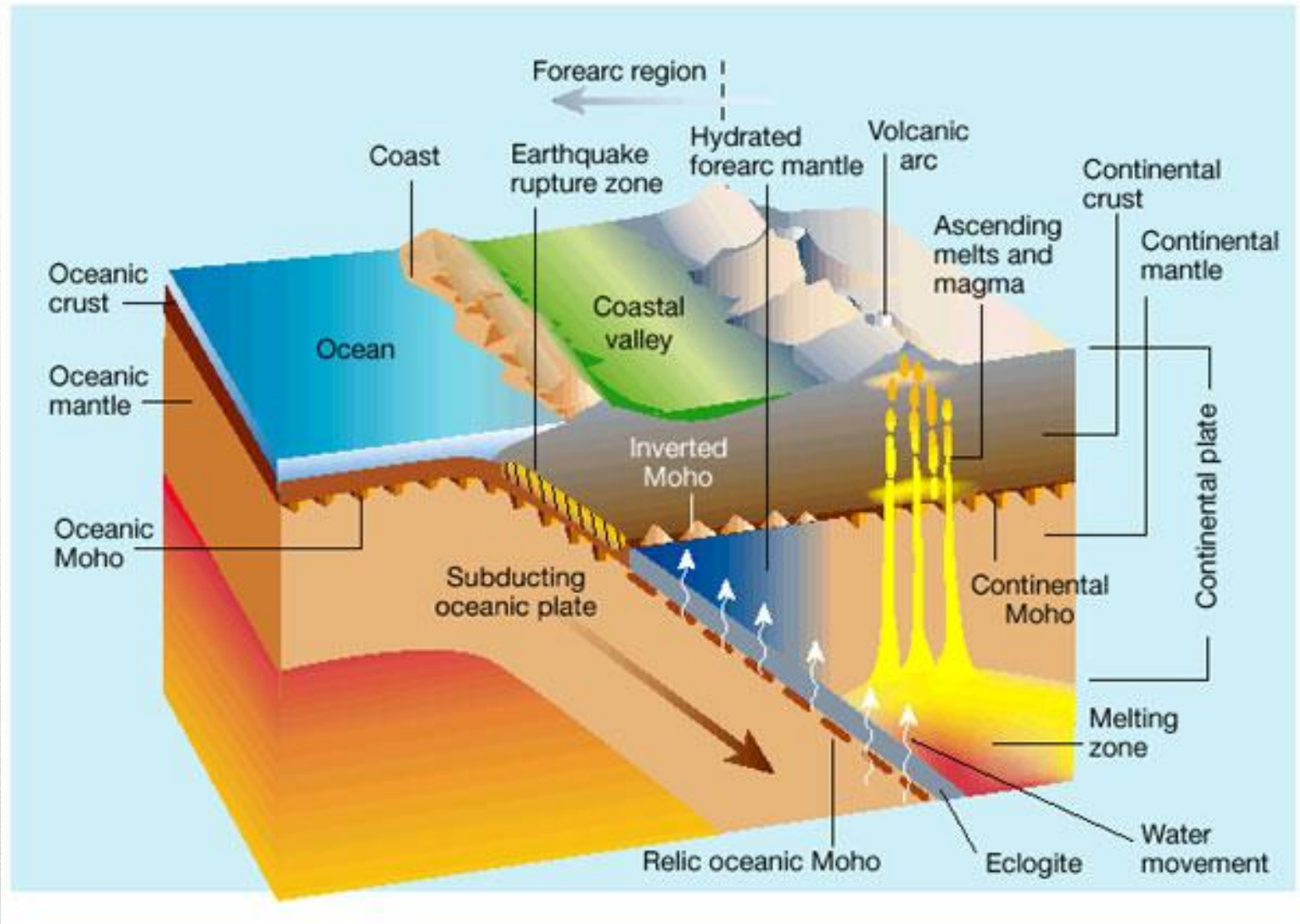
Seafloor Spreading is the Mechanism for Plate Tectonics

- Mid-oceanic Ridges or Spreading Centers are continuously adding to the edges of the lithosphere
 - The other edges of the lithospheric edges are being destroyed at Subduction Zones around the Earth
 - Continents do not move through oceanic crust; they are carried along with it with the movement of the plates
 - The creation of lithosphere at the Ridges is balanced by the consumption of the lithosphere at Subduction Zones
 - The Earth remains constant, neither growing nor shrinking
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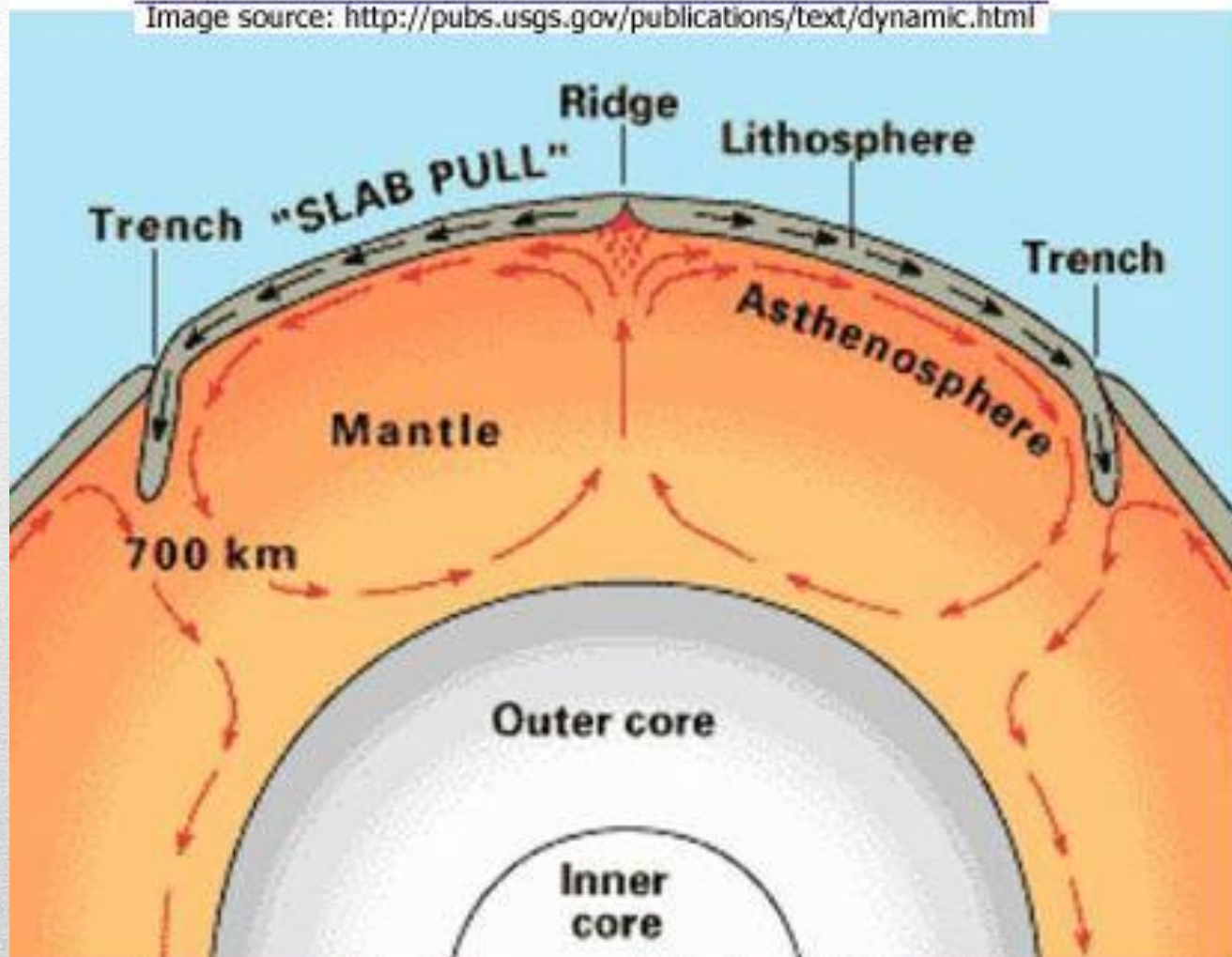
Sinking Plates Generate Earthquakes

- **How do sinking plates generate earthquakes and volcanoes**
 - When cold wet ocean crust is **subducted** under the continental crust, it comes in contact with the asthenosphere, creating **magma**
 - The **magma begins to rise**, the **continental crust is pushed up and volcanoes are formed**
 - **Earthquakes** occur when the relatively cooler sinking lithosphere comes in contact with the hot asthenosphere
 - This **contact causes the rock to cool and crack**, causing earthquakes
 - **Plate Tectonics is the Unifying Theory for geology**
 - **It explains an enormous variety of phenomena**
-



The Forces That Cause Plate Tectonics

Image source: <http://pubs.usgs.gov/publications/text/dynamic.html>



Types of Plate Boundaries

- There are three types of Plate Boundaries
- **Divergent Boundaries**
 - Where neighboring plates are pulling apart
 - New Lithosphere is released here expanding the ocean floor
 - These are ocean ridges or continental riffs
 - ❖ Examples are the Atlantic Ocean Ridge or the Red Sea Riff



Types of Plate Boundaries

- Convergent Boundaries

- These are where plates merge together

- There are three basic convergent boundaries

- ❖ Ocean-Continental Boundaries – Ocean plate subduct under the Continental Crust

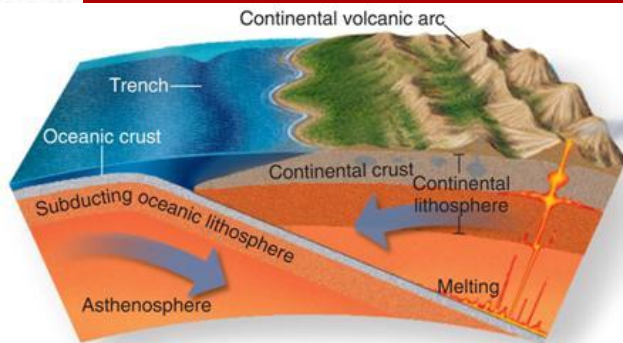
- Creates – **trenches, volcanoes** – Chilean Mountains and Trench

- ❖ Ocean-Ocean Boundaries – Older Ocean plate subduct under the newer Ocean plate

- Creates – **volcanic islands, submarine trenches**- Japan and Mariana Trench

- ❖ Continental-Continental Boundaries – no subduction happens, uplift occurs

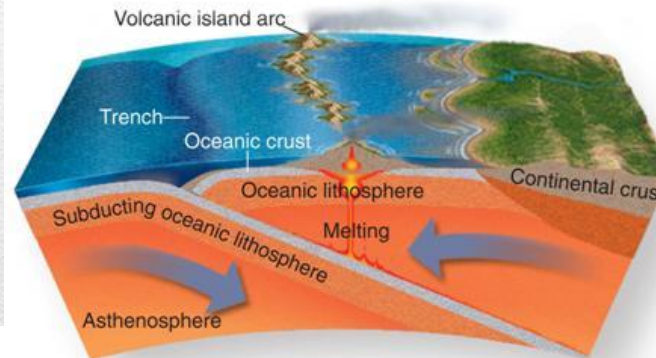
- Creates- **mountain ranges**- Himalayan Mountains



Oceanic-Continental Boundary
When oceanic and continental plates converge, the oceanic plate must subduct beneath the continental plate because the density of thick continental crust is too low to permit it to sink into the asthenosphere.

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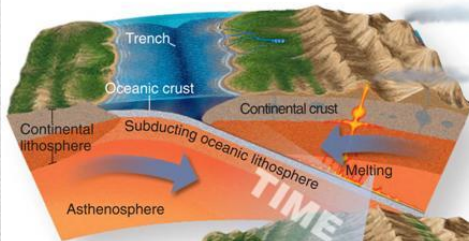
Fig 12.26



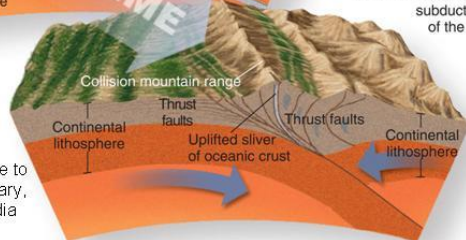
Oceanic-Oceanic Boundary
When a convergent boundary forms between plates of oceanic lithosphere, the plate that is older, thicker, and denser subducts the less dense plate.

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Fig 12.26



Continental-Continental Bound.
When subduction brings two continents together limited subduction may occur, but the buoyancy of continental crust eventually stops the subduction. The contraction of crust in the collision zone doubles the thickness of continental crust and creates high mountains. Slivers of oceanic crust are commonly uplifted in the mountain range and record the basin consumed by subduction prior to collision of the continents.



Himalayas are due to this sort of boundary, the collision of India with SE Asia.

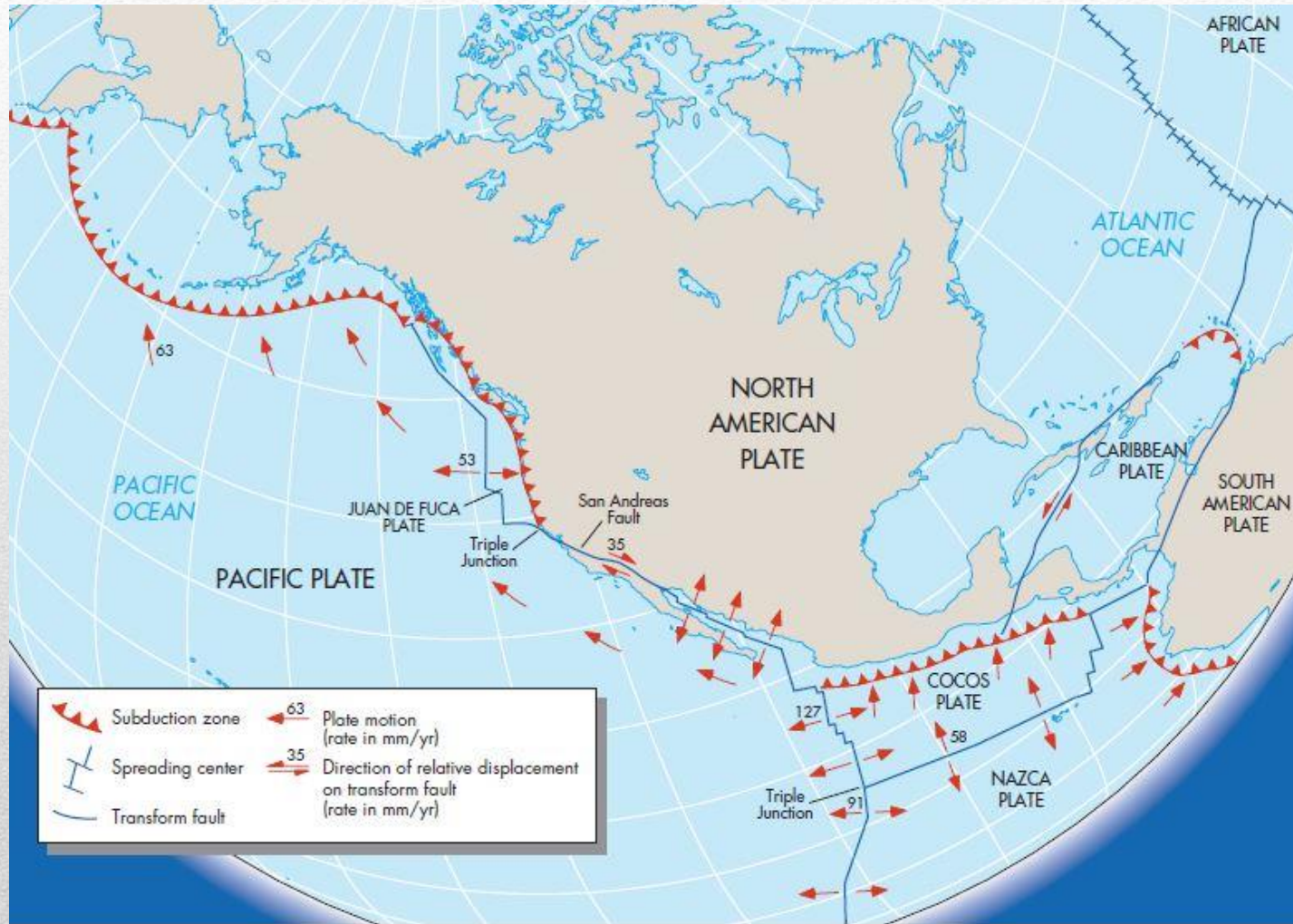
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Fig 12.26

Transform Boundaries

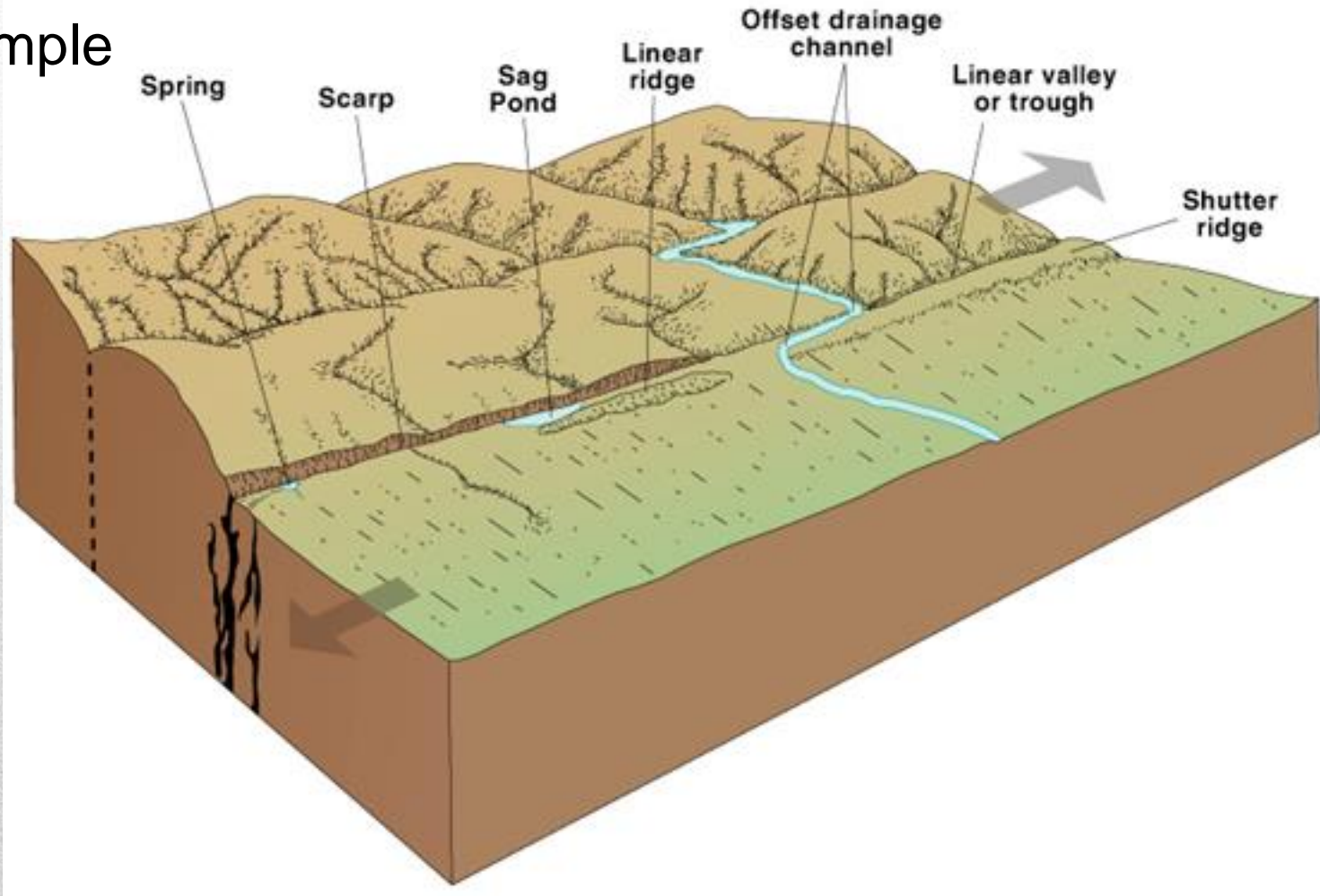
- A Transform Fault or Strike Slip Fault
 - Where the edges of two plates slide past each other
 - Contains a series of riffs (spreading) along the fault
 - ❖ Best known- **San Andreas Fault in California**
 - ❖ Causes many earthquakes
 - ❖ San Francisco on its way to the Gulf of Alaska
 - ❖ Also found in **Turkey**
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Triple Junction Transform Boundary



Landform from Transform Faults

Example



Rates of Plate Motion

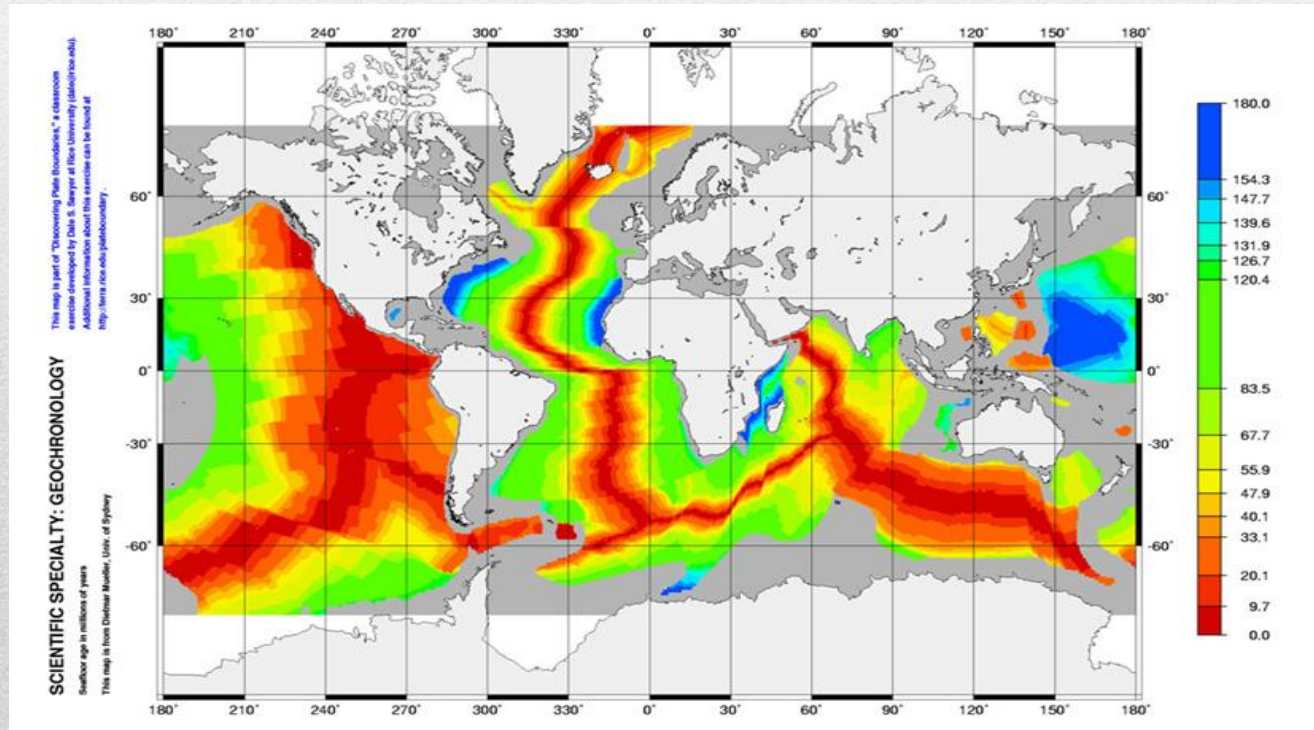
- **Plate Motion is a Fast Geologic Process (comparatively)**
 - **Plates move a few centimeters per year (about as fast as your fingernails grow)**
 - **This can cause some features, streams or rocks to be displaced over time where the feature crosses the fault**
-

Detailed Look at Seafloor Spreading

- By the 1950's the theory of Continental Drift accepted
 - Supported by depth soundings
 - Found seamounts/ridges or trenches
 - Seafloor spreading
 - 1960's new theory- by Harry Hess and Robert Dietz
 - Mechanism for continental drift, mid ocean ridges form from rising mantle creating ridges, spreading the ocean floor
 - Verified by the Paleomagnetism—reversal of pole magnetism
-

Sea Floor Spreading

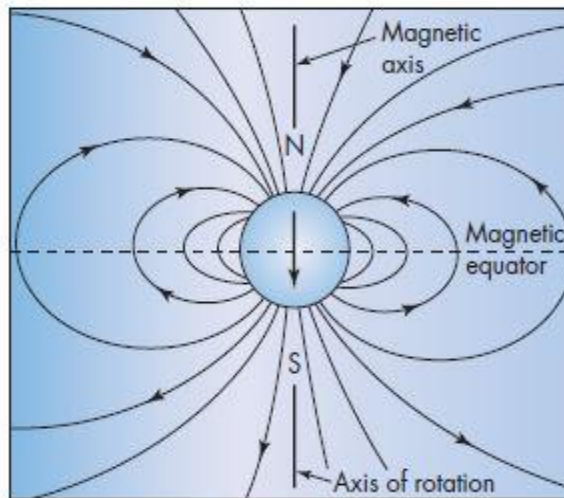
- The Validity of Seafloor Spreading from three sources:
 - Identification and mapping of the oceanic ridges
 - Dating of volcanic rocks on the floor of the ocean
 - Understanding and mapping the paleomagnetic history of the ocean basins



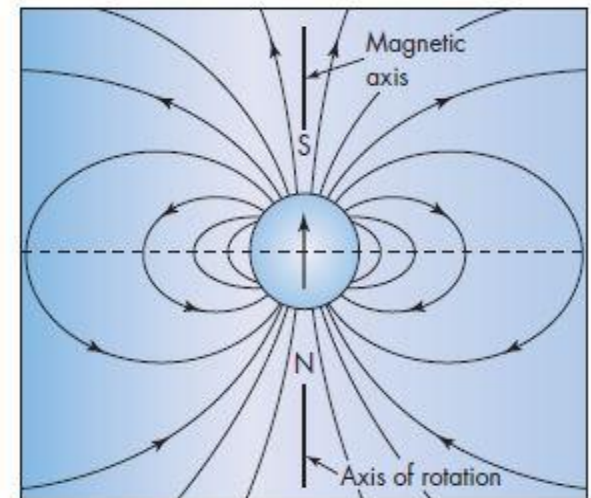
- **Paleomagnetism**

- Study of Paleomagnetism history helps to understand sea floor spreading and plate tectonics
- Because of the convection processes within the earth, the earth has experienced periodic magnetic reversals
- This produces magnetic “stripes” in the iron bearing minerals found on the earth’s floor

- **New crust is formed and returned to the mantle every 200 million years**

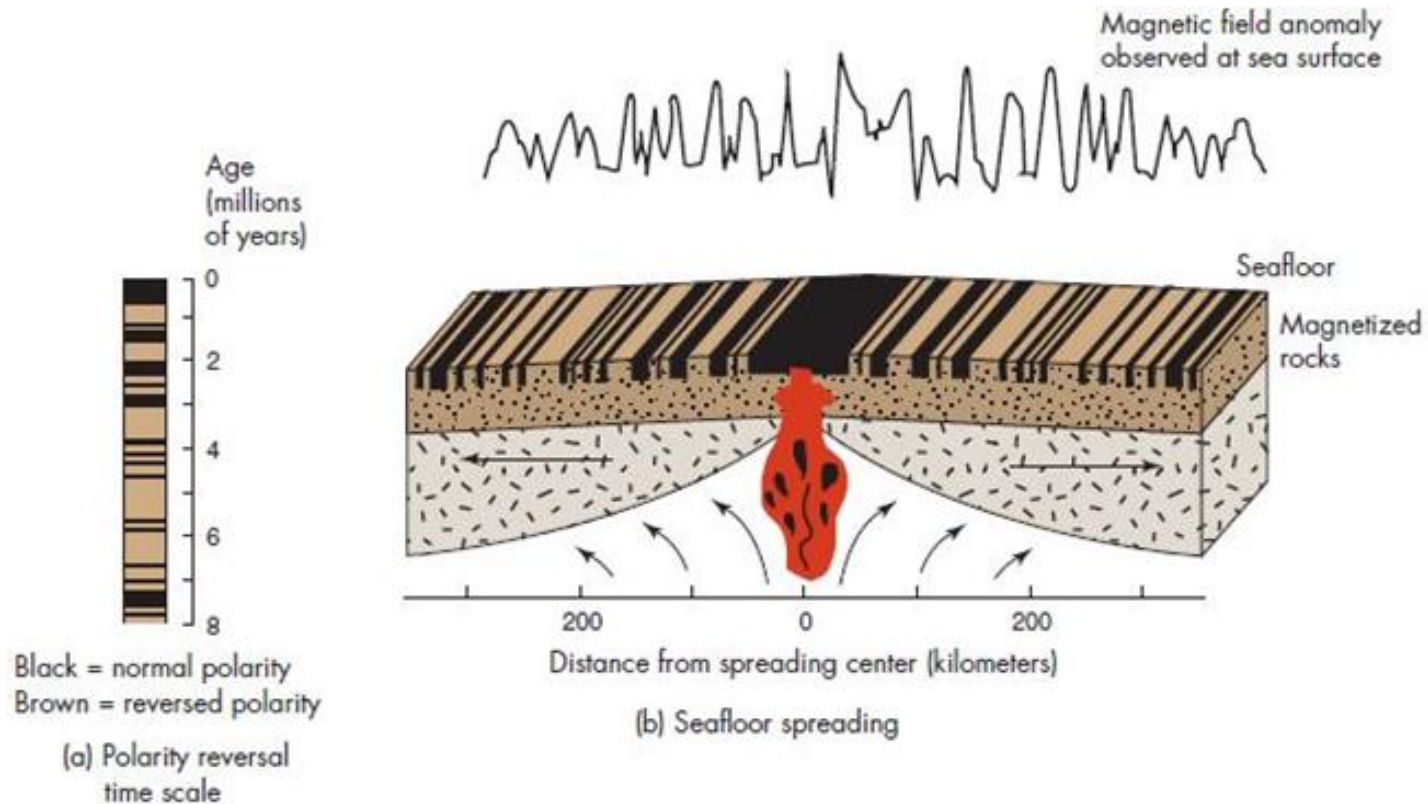


(a) Normal polarity

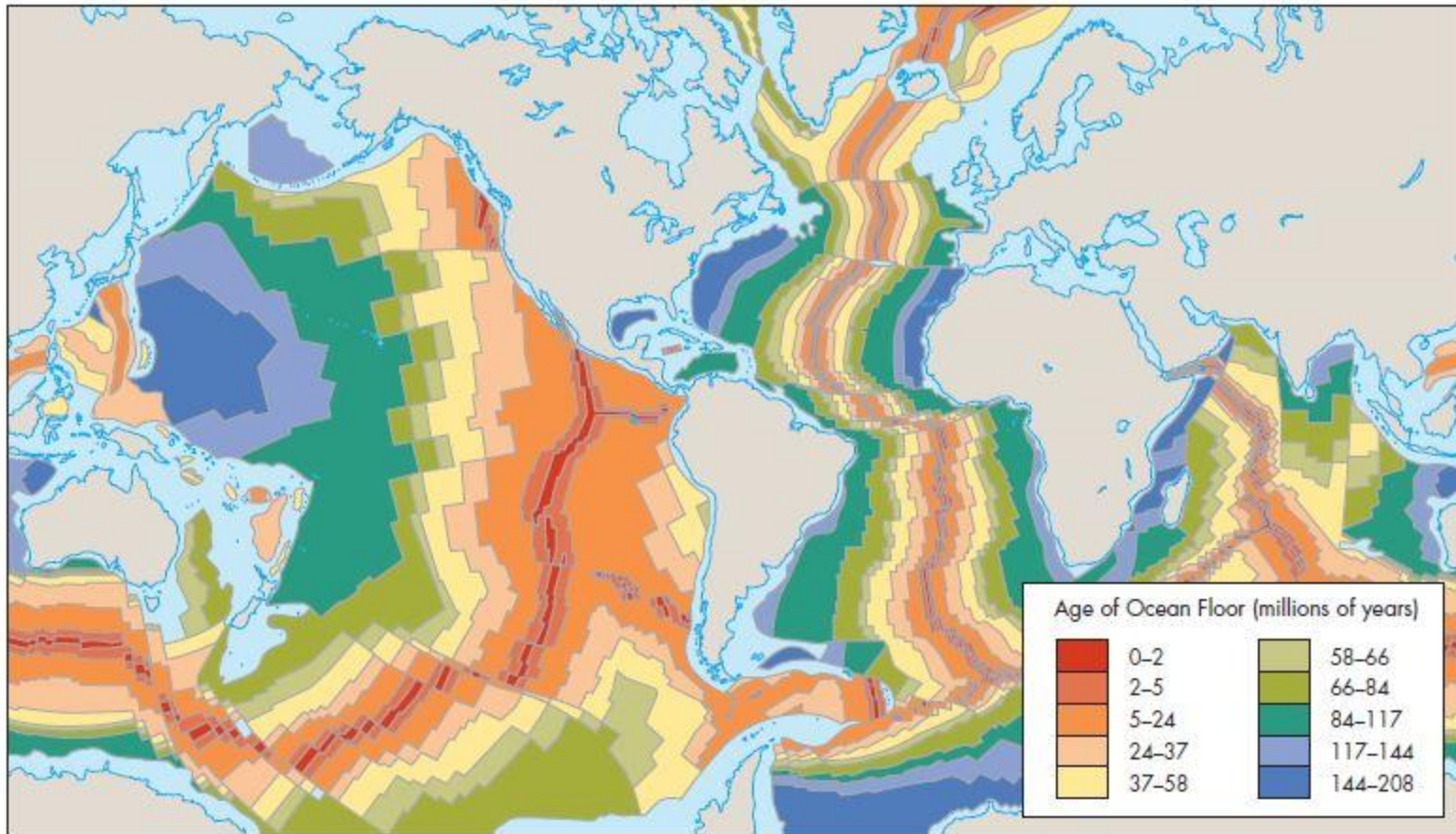


(b) Reversed polarity

Paleomagnetism



Age of the Sea Floor

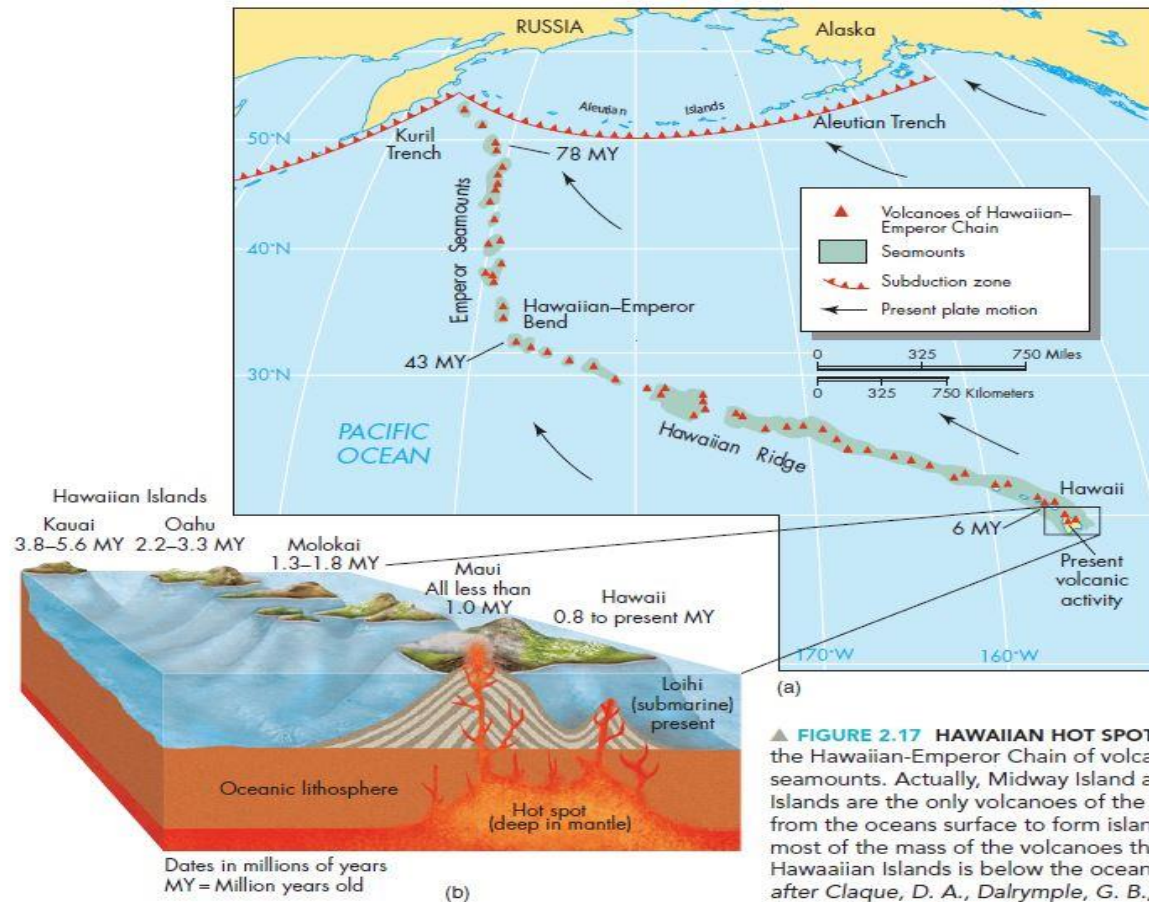


Hot Spots

- Spots of volcanic activity caused by a thin Earth's crust allowing the magma to move to the surface
- These are called **Hot Spots or Mantle Plumes**
- Hawaii and Yellowstone fall on such Hot Spots
- As the plate moves across the Pacific Hot Spot, a **trail of islands are left, creating the Hawaiian Island archipelago**
- These islands are called seamounts
- Hot Spots help to explain volcanic activity in the middle of plates and help to distinguish the direction of the plate's movement



Hot Spot Creating Hawaii



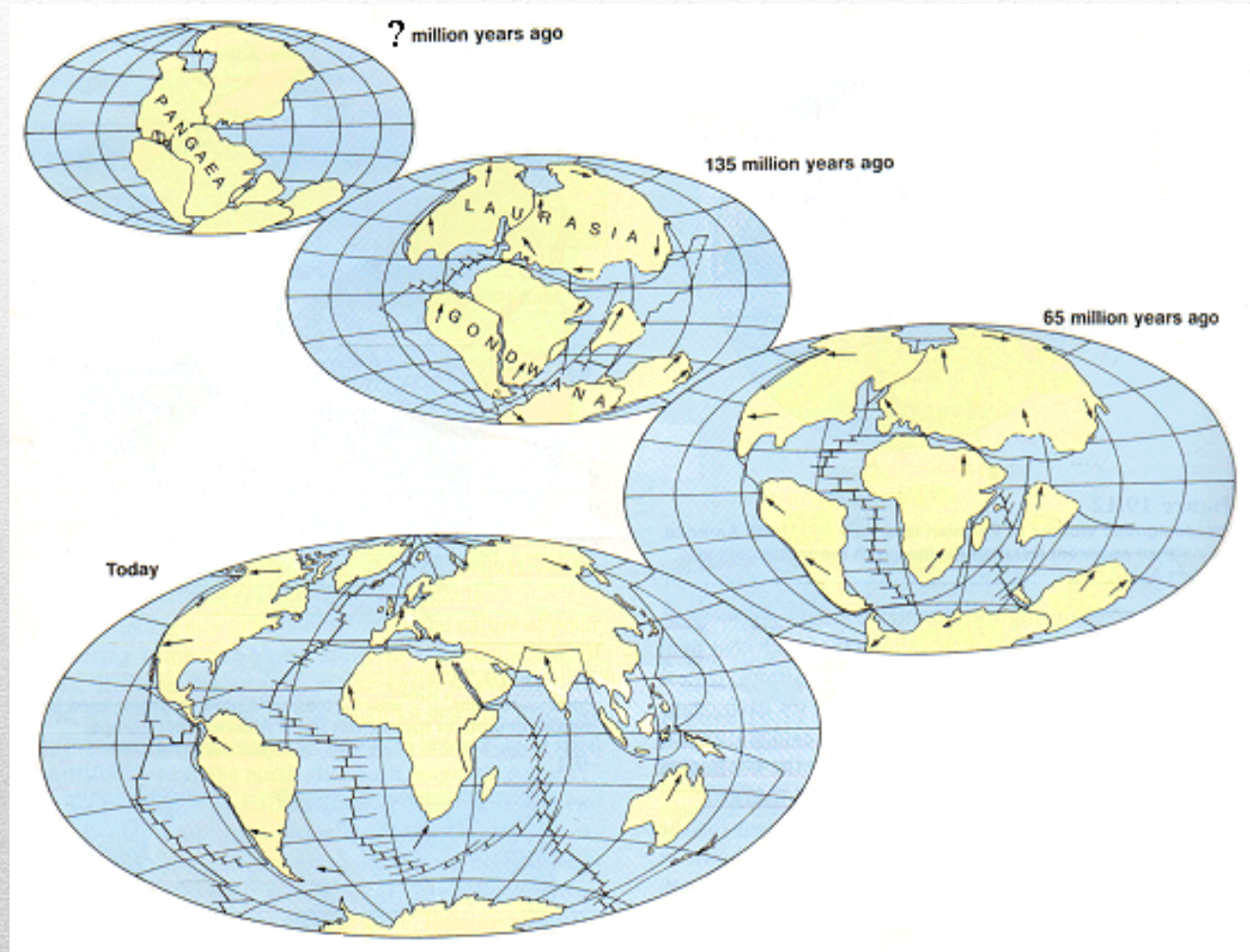
▲ FIGURE 2.17 HAWAIIAN HOT SPOT (a) Map showing the Hawaiian-Emperor Chain of volcanic islands and seamounts. Actually, Midway Island and the Hawaiian Islands are the only volcanoes of the chain that protrude from the oceans surface to form islands. Notice that most of the mass of the volcanoes that form the Hawaiian Islands is below the ocean surface. (Modified after Claque, D. A., Dalrymple, G. B., and Moberly, R. 1975. Petrography and K-Ar ages of dredged volcanic rocks from the western Hawaiian Ridge and southern Emperor Seamount chain. *Geological Society of America Bulletin* 86:991–98) (b) Sketch map showing the Hawaiian Islands, which range in age from present volcanic activity to about 6 million years old on the island of Kauai.

Pangaea and Present Continents

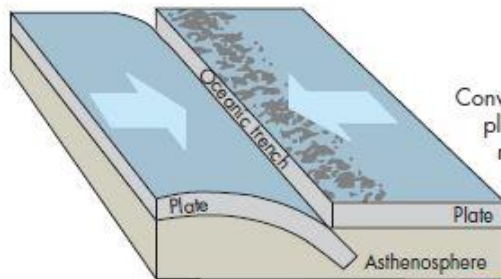
- Summary of the time line from Pangaea to the Present
 - 450 million years – 5 continents- merged together to form Pangaea
 - Next 200 million years; one continent
 - 200 million years – Pangaea starts to break up– Laurasia & Gondwanaland- then to even smaller pieces
 - 135 million years -- North and South Atlantic Oceans begin to open, separating South America and Africa, Mediterranean Sea began to close as Africa began to rotate northward toward Asia
 - 65 million years --North and South Atlantic Oceans joined; South America was new Continent and moving westward, Andes growing, as South America overrides the Pacific Plate. Rockies were rising but not the Sierras
-



Pangaea

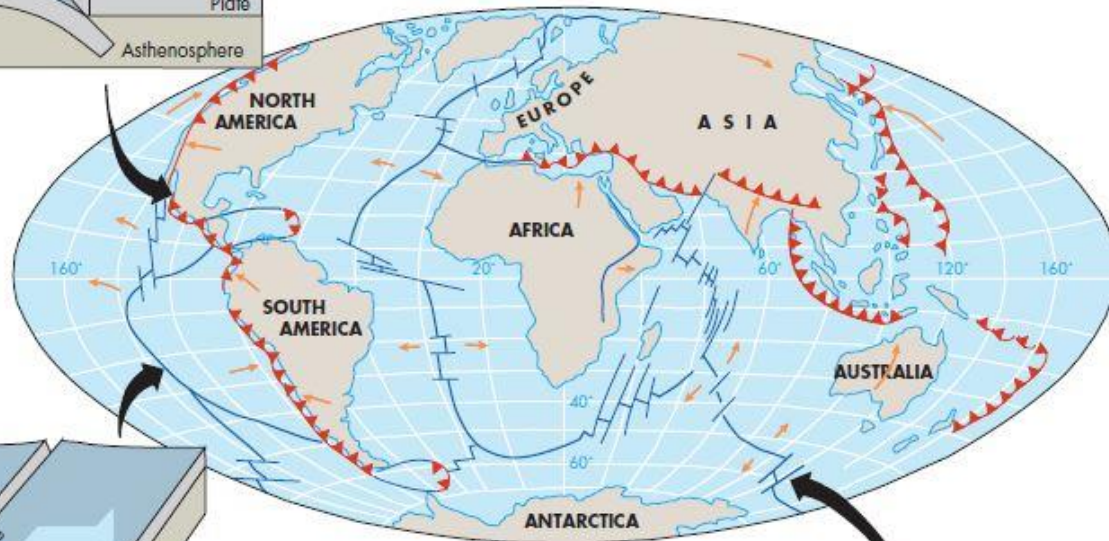
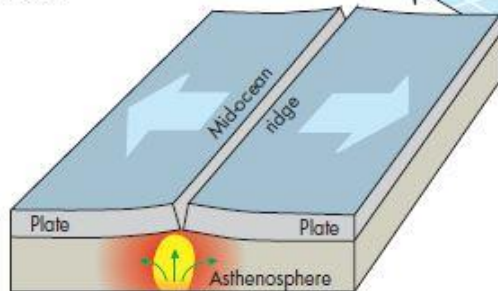


Pangaea begins to break apart into present continents



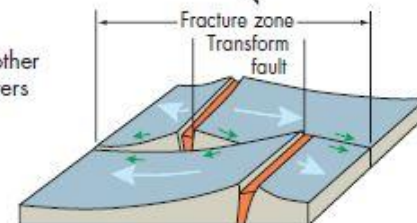
Convergent plate boundary—
plates converge, producing a subduction zone,
mountains, volcanoes, and earthquakes

Divergent plate boundary—
plates diverge at mid-ocean
ridges



(d) Present

Transform fault—
plates move laterally past each other
between seafloor spreading centers



Assembly & Breakup of Pangaea

- “Today” South America connected to North America
 - North America separated from Europe
 - Europe, Australia has split from Antarctica
 - India collided with Eurasia-thrusting up the Himalayas
 - All continents are still in motion except for Antarctica
 - Africa is splitting along Great Rift Valley rotating counterclockwise



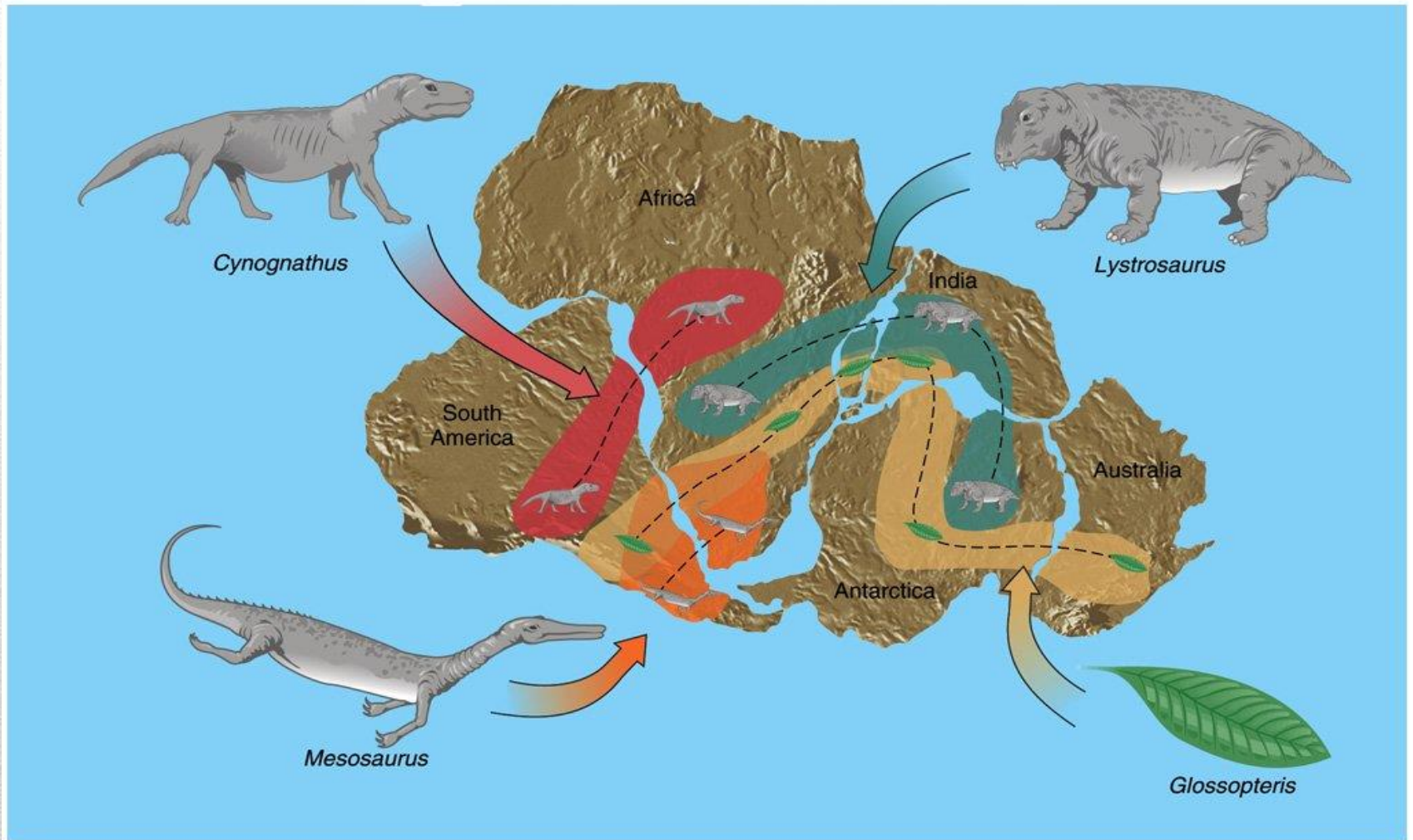
Future of the Continents

- 50 million years from now
 - Australia will straddle the equator is huge tropical island
 - Africa may pinch the Mediterranean shut
 - East Africa becomes large island like Madagascar
 - The Atlantic will widen while the Pacific will shrink
 - Southern California, now a chilly island will pass San Francisco heading for its ultimate destination in the Aleutian Trench of the Gulf of Alaska
-

Understanding Plate Tectonics Solves Long-Standing Geologic Problems

- Understanding Plate Tectonics theory helped to clear up two geological mysteries:
 - How did fossils of the same animals and plants end up in both South America and Africa?
 - Evidence of ancient glaciation on several continents with inferred directions of ice flow were the same as if there was only one continent?
-

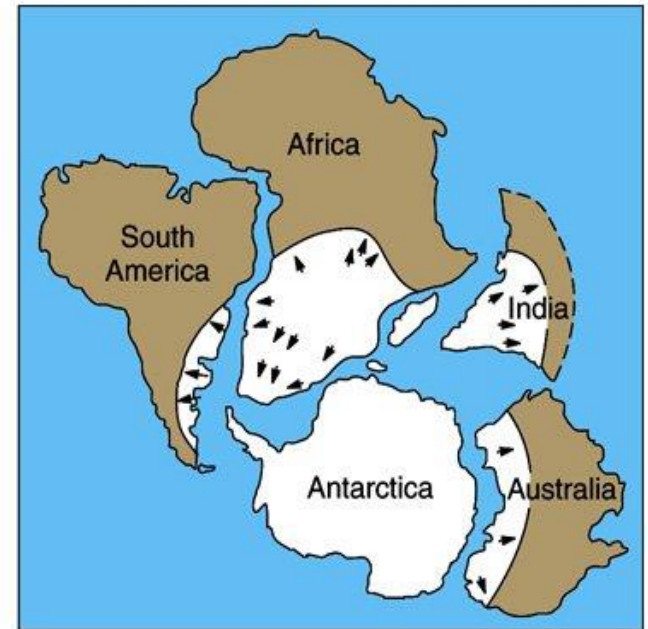
How the Distribution of Animal and Plant Fossils was explained across the continents



How the Breakup of Gondwanaland Explained Glaciation Motion



A



B

How Plate Tectonics Works: Putting it Together

- Driving Mechanisms that move the plates

- This could be call a “push me pull me” method

- ❖ The mid-ocean ridge pushes new magma up creating new ocean floor, moving the old crust outward
 - ❖ The old crust moves outward from the mid-ocean ridge
 - ❖ As this happens, the new crust pushes the lighter continental plates over the asthenosphere
 - ❖ The continental plate moves until it hits another plate
 - ❖ Depending on the kind of plate, there will be a subduction or a collision, with either volcanoes or trenches created or huge mountain ranges built
 - ❖ Convection in the mantle and asthenosphere guarantee this process will continue
-

Plate Tectonics and Hazards

- Plate Tectonics Affect Us All
 - The Linkages of plate tectonics to hazards is obvious
 - Where plate boundaries are located, volcanoes and earthquakes can occur
 - Conclusions from these occurrences are:
 - ❖ Divergent boundaries can be associated with volcanoes and earthquakes
 - Example: Iceland
 - ❖ Transform boundaries – earthquake hazards are intensified, and where mountains are found landslides and flooding may be experienced
 - ❖ Convergence Boundaries cause many hazards,
 - Mountainous areas have landslides and flooding
 - Volcanoes and earthquakes can be expected
 - Plate Tectonics are associated with the natural hazards found around the world
 - Man only makes the hazards into disasters and catastrophes
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